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Species richness and conservation status of medium and large terrestrial mammals from four Sky Islands in Sonora, northwestern Mexico

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Abstract: We present the first systematic checklist of medium and large terrestrial mammals on four mountain ranges known as Sky Islands, in northeastern Sonora, Mexico. We used camera traps for recording mammals, with which we documented 25 wild species. Two of the native species are in the IUCN Red List and four are threatened at the national level. We did not document seven wild species with potential distribution at study sites, probably due to limited availability of habitat and/or local extirpation of species. The importance of this work is that we generated an inventory of medium and large mammals in an area considered poorly studied and highly diverse.

Key words: The Apache Highlands; mammals; inventory; camera traps

INTRODUCTION

The state of Sonora in northwestern Mexico has extensive topographical and climatic variability, as well as different types of vegetation and soil, which combined enable the occurrence of a relatively large number of species of mammals (Caire 1978), making it the eighth state with most species in Mexico (Castillo-Gámez et al. 2010). Estimated species richness in the state has changed over time due to the increasing collection of wild specimens, changes in taxonomic nomenclature, and whether or not potentially occurring species and introduced species are included in species counts (Burt 1938; Ramírez-Pulido et al. 1986; Caire 1997; Castillo-Gámez et al. 2010).

One of the first studies to accumulate information about the richness of mammal species in Sonora was written by Burt (1938), who reported 139 native and two introduced species in the state. Subsequently, Caire (1978) published the most comprehensive work on mammal fauna in Sonora, reporting 120 wild species and two introduced species based on field surveys and examination of approximately 13,000 specimens from scientific collections. By consulting various publications and biological collections, Ramírez-Pulido et al. (1986) reported 127 species with geographical distribution in the state of Sonora.

Caire (1997) summarized and updated his previous work, and reported 124 species of mammals, of which three were introduced rodents, eight domestic species and 28 species were of potential distribution in Sonora, despite a lack of verified records.

The latest review of the mammals in Sonora was by Castillo-Gámez et al. (2010), who reported 126 species of land mammals, with most species belonging to Rodentia and Carnivora. This list excludes species endemic to the islands of the Gulf of California and considers only those species with at least one specimen deposited in a biological collection. The authors documented 30 species under conservation status by Mexican laws.

Previous knowledge indicates that the northeastern region of the state is home to the greatest number of mammalian species (Caire 1978), still maintaining one of the largest most comprehensive assemblages at a national and international level including species with large body size (>20 kg, Morrison et al. 2007). However, there is an evident need to explore the region which covers the state boundary between Sonora and Chihuahua due to the lack of systematic inventories of mammalian species (Marshall et al. 2004; Castillo-Gámez et al. 2010).

Information gaps in the northeastern region of the state of Sonora include data on the presence,

distribution, ecology of populations and communities, making conservation status uncertain for most species (Marshall et al. 2004). Advances in research on the assemblage of mammals have been held back because of lack of information on which to base management or conservation plans. The aim of this paper is thus to update the inventory of species of medium and large land mammals, based on fieldwork in four mountain ranges known as Sky Islands in northeastern Sonora, Mexico.

MATERIALS AND METHODS

Study site

Fieldwork was carried out in the northeastern area of Sonora state, Mexico, in 2009. Seven sites located in four Sky Island mountain ranges in the region known as the Apache Highlands (Marshall et al. 2004) were surveyed (Figure 1; Table 1). Three of the study sites fell within two polygons of the protected area known as Reserva Forestal Nacional y Refugio de Fauna Silvestre Ajos-Bavispe (RFyRFS Ajos-Bavispe).

Data collection

We documented species of terrestrial mammals using motion-activated camera traps (Table 2), which were placed on paths identified as wildlife travel routes (Monterroso 2013; Si et al. 2014). The spatial separation between each camera was of approximately 1 km, varying from 0.6 to 1.2 km due to the roughness of terrain in each sampled area. In order to have a representation of the different dietary guilds (omnivores, herbivores and

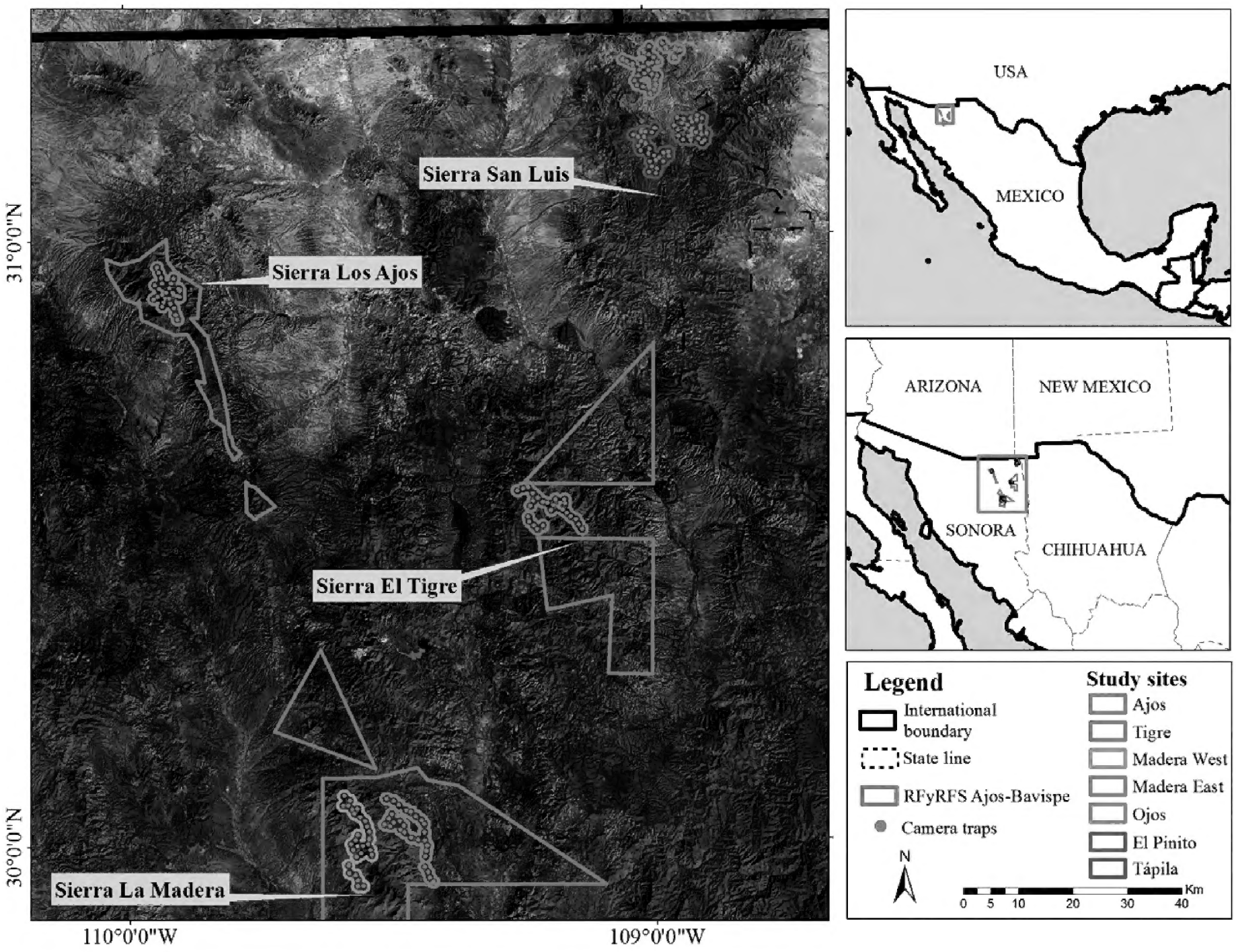

Figure 1. Locations of seven study sites in four Sky Islands at northwestern Mexico.

Table 1. Geographic location and vegetation types of seven study sites of four Sky Islands at northwestern Mexico. Caption: (a) *Pinus-Quercus* forest, (b) *Quercus* sp. forest, (c) *Quercus-Pinus forest*, (d) natural grassland, (e) mesquite forest, (f) induced grassland, (g) open lowland forest, (h) *Pinus* forest (INEGI 2014).

Site	Latitude	Longitude	Elevation (m)	Precipitation (mm)	Mean temperature range (°C)	Vegetation type
Ajos	30°56′37.6″W	109°57′31.5″N	1600–2000	400–600	12–14	a, b, c
Tigre	30°33′11.0″W	109°10′08.5″N	1200–2200	400–600	14–16	b, d
Madera West	29°59′36.2″W	109°33′21.2″N	1200–2001	400–600	16–20	b, c
Madera East	30°00′53.9″W	109°25′42.4″N	800–1200	400–600	16–20	d, e, f
Ojos	31°16′42.4″W	108°59′56.1″N	1400–1600	400–600	14–16	a, d
El Pinito	31°11′23.9″W	108°56′06.2″N	1600–1800	125–600	14–16	a, g, h
Tápila	31°08′30.1″W	108°59′45.9″N	1600–1800	400–600	14–16	d, c, g

Table 2. Camera traps numbers and survey effort in seven study sites in the state of Sonora, Mexico.

Site	No. of camera traps	Sampling effort (camera days)
Ajos	28	1,107
Tigre	29	805
Madera West	28	942
Madera East	28	817
Ojos	31	930
El Pinito	27	1,003
Tápila	25	1,064

carnivores), we placed a combination of food attractants (oats, corn, sardines and vanilla essence) at a distance of 3–5 m in front of each camera trap.

Cameras were attached to trees at a height ranging between 0.5–1 m and oriented in a south to north direction to avoid being activated by direct sunlight (Si et al. 2014; Swan et al. 2014). All cameras were programmed to operate continuously (24 h/day) at one-minute intervals, taking three continuous photographs (digital images), when they were activated. Two models of digital cameras were used: Wildview Xtreme 2.0® and Wildview Xtreme 5.0® (Wildview, Grand Prairie, USA). At each site where a camera was placed, geographic coordinates were recorded, using a GPS.

Species identification in camera images was based on field guides by Kays and Wilson (2002) and Reid (2006), except for jackrabbits (genus *Lepus*) for which we relied on expert opinion because the combination of position, light, and definition made species identification of jackrabbit images difficult. Thus digital images of jackrabbits were sent to six researchers with experience with this taxon, in order to properly identify the species. Subsequently, by majority opinion, a consensus was reached and the species name was assigned. The nomenclature used throughout the manuscript follows that of Wilson and Reeder (2005).

Data analysis

Sampling effort was calculated by multiplying the total number of cameras placed (n=196), by the number of days they were operating (1d = 24 hours, Tobler et al. 2008; Porfirio et al. 2014). We applied a 24 h interval between photographs of the same species to ensure data independence (Tobler et al. 2008; Porfirio et al. 2014), and determined the species with the highest and lowest number of independent photographic records. Thus, we calculated a photographic capture rate (number of independent photographs of each species divided by the sampling effort in days), which we used as a measure of relative abundance (Carbone et al. 2001; Porfirio et al. 2014).

We determined the efficiency of sampling to update the inventory in two ways: by comparing the observed richness versus species richness of potential occurrence reported in two literature sources: Caire (1978), Hall (1981), and by comparing the observed percentage of species richness, versus the percentage of expected species derived from a richness estimator. The results from the above comparisons were used to determine how many species we would expect to detect at the monitoring sites and as a way of determining whether the applied method and sampling effort were adequate.

The analysis included only the records of wild mammals, and only those species with adult body weight exceeding 500 g. We believe that only mammals with this minimum weight can be frequently detected and reliably identified using camera traps.

In order to obtain expected species richness from bibliographic sources, distributional maps by Caire (1978) and Hall (1981) were used; we assumed a species was present if its global distribution range overlapped our study area. Because the monitoring focused on coniferous forests, including pine, pine-oak forest, oak-pine forest and low open woodland (INEGI 2014), we excluded species from analyses that do not typically occur in these habitats. Thus, although their ranges overlapped the study area, we excluded *Cynomys ludovicianus* (Ord, 1815), *Vulpes macrotis* Merriam, 1888, *Antilocapra americana* (Ord, 1815), *Bison bison* (Linnaeus, 1758), *Cervus elaphus* Linnaeus, 1758 and *Lontra longicaudis* (Olfers, 1818) (O'Gara 1978; McGrew 1979; Meagher 1986; Hoogland 1996; Lavivière 1999; Peek 2003). *Puma yagouaroundi* (É. Geoffory Saint-Hilaire, 1803) was excluded because there are no verified records (collected specimens or photographs) for the state of Sonora (Brown and López-González 2000).

In the second comparison, we used the Jackknife 1 estimator because it has been shown to provide better results in relation to other estimators of diversity (Tobler et al. 2008). The estimate was calculated using the EstimateS Version 9.1.0. software (Colwell 2013), through which a species accumulation curve was generated with 1,000 iterations. For the construction of the curve, we used the maximum number of days camera traps recorded a species (40 d) as sampling effort and extrapolated to double this maximum (80 d), as an estimate of the number of species that would be recorded with increased sampling effort.

RESULTS

At the seven monitoring sites, we placed camera traps at 196 different locations, which together remained active for 6,668 days (Table 2; Figure 1). We obtained a total of 8,243 photographs of terrestrial mammals of medium and large size.

We recorded a total of 25 wild species belonging to five orders, 11 families and 21 genera, with the order Carnivora having the highest number of species (Table 3; Appendix). Of the species recorded, four are within

Table 3. Species list of medium and large land mammals detected with camera traps in Northeastern Sonora, Mexico. Conservation status according to IUCN Red List (2014) and Mexican legislation (SEMARNAT 2010). IUCN Categories: (LC) Least Concern, (DD) Data Deficient, (NT) Near Threatened. NOM-059: (A) Threatened, (P) Endangered. Study sites: Ajos (1), Tigre (2), Madera West (3), Madera East (4), Ojos (5), El Pinito (6), Tápila (7).

Order	Family	Scientific name	Common name	IUCN	NOM-059	Study site
Didelphimorphia	Didelphidae	*Didelphis virginiana* Kerr, 1792	Virginia Opossum	LC		2,3,4,5,6,7
Rodentia	Sciuridae	*Sciurus arizonensis* Coues, 1867	Arizona Grey Squirrel	DD	A	1,2,3
		Sciurus nayaritensis J. A. Allen, 1980	Mexican Fox Squirrel	LC		2,5,6,7
		Otospermophilus variegatus (Erxleben, 1777)	Rock Squirrel	LC		1,2,3,4,5,6,7
Lagomorpha	Leporidae	*Lepus alleni* Mearns, 1890	Antelope Jackrabbit	LC		4,5
		Sylvilagus audubonii (Baird, 1858)	Desert Cottontail	LC		2,3,4,5,7
		Sylvilagus floridanus (J. A. Allen, 1890)	Eastern Cottontail	LC		1,2,3,5,6,7
Carnivora	Felidae	*Leopardus pardalis* (Linnaeus, 1758)	Ocelot	LC	P	1
		Lynx rufus (Schreber, 1777)	Bobcat	LC		1,2,3,4,5,6,7
		Puma concolor (Linnaeus, 1771)	Cougar	LC		1,2,3,5,6,7
		Panthera onca (Linnaeus, 1758)	Jaguar	NT	P	1
	Canidae	*Canis latrans* Say, 1823	Coyote	LC		2,3,4,5,7
		Urocyon cinereoargenteus (Schreber, 1775)	Gray Fox	LC		1,2,3,4,5,6,7
	Ursidae	*Ursus americanus* Pallas, 1780	American Black Bear	LC		1,2,3,5,6,7
	Mustelidae	*Taxidea taxus* (Schreber, 1777)	American Badger	LC	A	4
	Mephitidae	*Conepatus leuconotus* (Lichtenstein, 1832)	American Hog-nosed Skunk	LC		1,2,3,4,5,6,7
		Mephitis macroura Lichtenstein, 1832	Hooded Skunk	LC		1,2,3,4,5,6,7
		*Mephitis mephitis (*Schreber, 1776)	Striped Skunk	LC		1,2,3,4,5,6,7
		Spilogale gracilis Merriam, 1890	Western Spotted Skunk	LC		2,3,4,5,6,7
	Procyonidae	*Bassariscus astutus* (Lichtenstein, 1830)	Ringtail	LC		1,2,3,5,6,7
		Nasua narica (Linnaeus, 1766)	White-nosed Coati	LC		1,2,3,4,5,6,7
		Procyon lotor (Linnaeus, 1758)	Raccoon	LC		2,4,5
Artiodactyla	Tayassuidae	*Pecari tajacu* (Linnaeus, 1758)	Collared Peccary	LC		2,3,4,5,7
	Cervidae	*Odocoileus hemionus* (Rafinesque, 1817)	Mule Deer	LC		5
		Odocoileus virginianus (Zimmermann, 1780)	White-tailed Deer	LC		1,2,3,4,5,6,7

a risk category in Mexican legislation (NOM-059; SEMARNAT 2010) and two within a risk category in the global IUCN Red List (IUCN 2014) (Table 3).

Species of wild mammals with the greatest number of independent photographic events were the white-tailed deer *Odocoileus virginianus* (Zimmermann, 1780), rock squirrel *Otospermephilus variegatus* (Erxleben, 1777) and gray fox *Urocyon cinereoargenteus* (Schereber, 1775) (Figure 2). Species with the lowest number of records were the jaguar *Panthera onca* (Linnaeus, 1758), ocelot *Leopardus pardalis* (Linnaeus, 1758) and American badger *Taxidea taxus* (Schreber, 1777) (Figure 2).

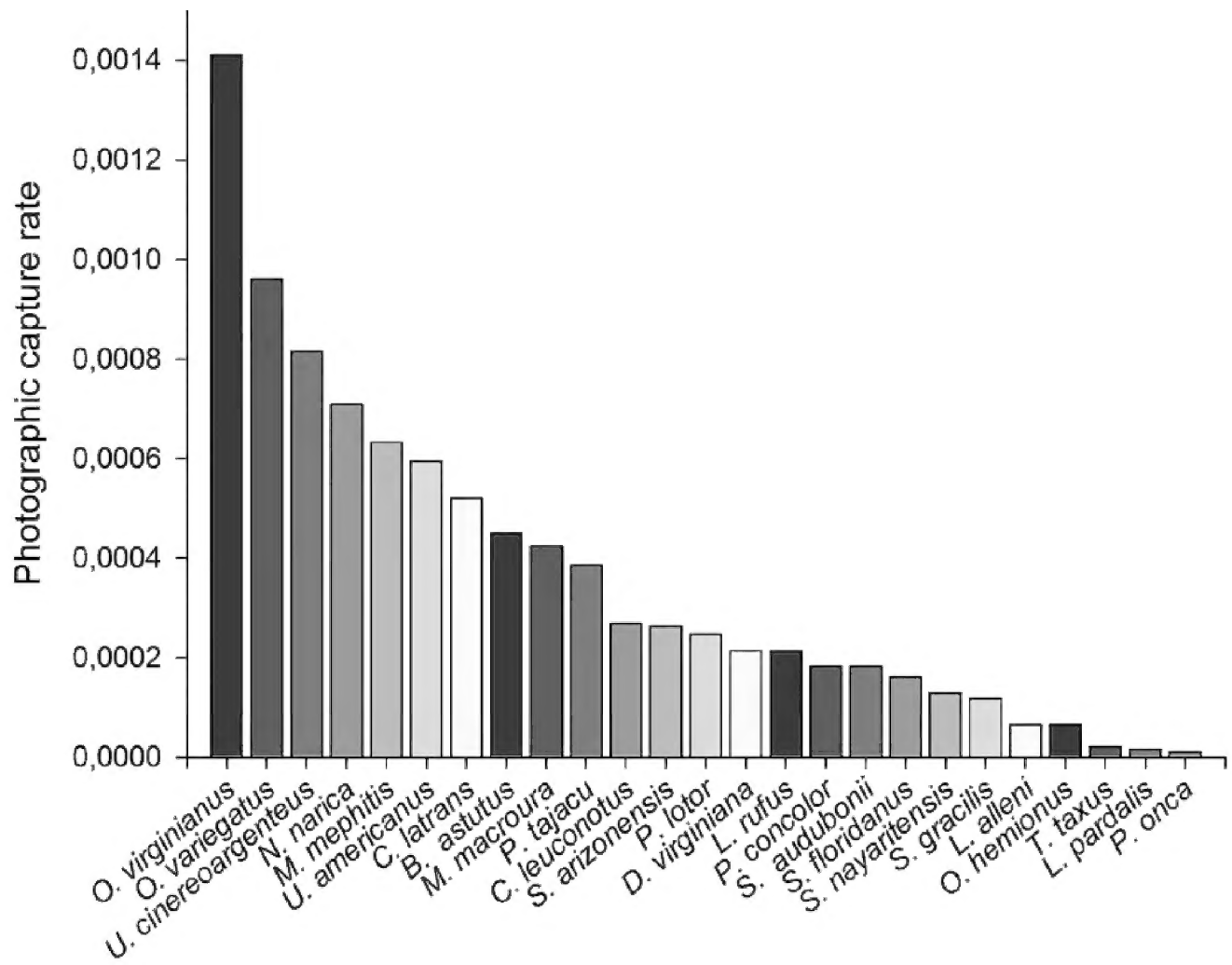

Figure 2. Photographic capture rate of 25 medium and large terrestrial mammals (body size >500 g) in northeastern Sonora, Mexico.

Based on the surveys of Caire (1978) and Hall (1981), there were potentially 32 species of medium and large sized land mammals at the study area. Having documented 25 species, we recorded 78.12% of the species reported by these authors.

Moreover, comparing the observed species richness of wild mammals (25 species) versus the estimated richness (Jackknife 1 = 25), we recorded 100% of expected medium and large mammals in the localities monitored, using this sampling method. Based on extrapolation of the sampling effort (80 d), additional species are unlikely to be detected (Figure 3).

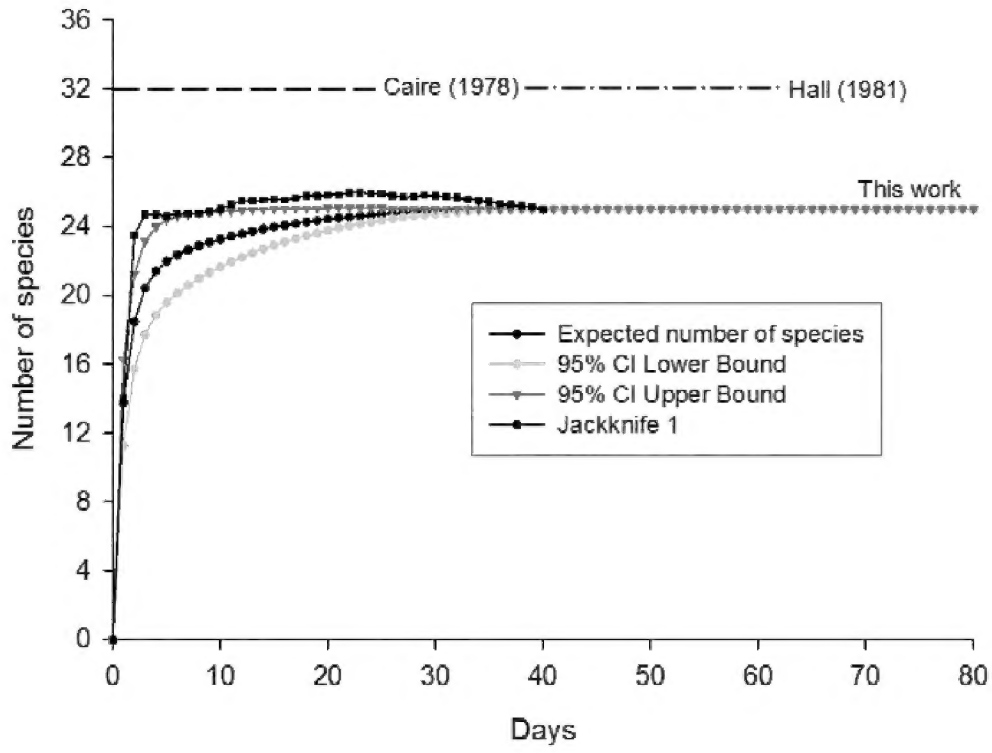

Figure 3. Species accumulation curve of medium and large terrestrial mammals (body size >500 g) documented with camera traps.

DISCUSSION

Five articles describing species richness for Sonora average of 17.5 (±15.15 *S.D.*) years between publications, ranging from eight to 40 years (Burt 1938; Caire 1978; Ramírez-Pulido et al. 1986; Caire 1997; Castillo-Gámez et al. 2010). Thus it is apparent that information has not been updated for most species of mammals in the state. The published studies are based on historical data, which depending on the author may overestimate the presence, diversity and distribution range of the different species, masking the current situation of mammals in the state.

In Sonora, a few species of medium and large-sized mammals have been more thoroughly studied, among them the ocelot, a species for which there is information about location, type of habitat and potential distribution (López-González et al. 2003). There is a relatively recent record (mid 1970s) for the occurrence of grizzly bear, *Ursus arctos* Linnaeus, 1758 (Gallo-Reynoso et al. 2008), a species that has been extirpated nationwide since about 1959 (Brown 1996). The jaguar appears to be the most well-studied mammal in the state, with historical (1900-2000) and recent species records (Brown and López-González 2001; Rosas-Rosas and Bender 2012; Gutiérrez-González et al. 2012), morphometric measurements of individuals killed at different localities (Brown and Lopez-Gonzalez 2001), proposals for reducing predator control on the part of cattle ranchers (Rosas-Rosas and Valdez 2010), characteristics of livestock depredation sites and habitat where the jaguar has obtained food (Rosas-Rosas et al. 2008; Rosas-Rosas et al. 2010), identification of individuals through photographic records (Rosas-Rosas and Bender 2012; Gutiérrez-González et al. 2012), and estimated population density (Gutiérrez-González et al. 2012).

In the northeastern area of Sonora, published studies have focused on species such as white-tailed deer *Odocoileus virginianus* (Coronel-Arellano et al. 2009; Lara-Díaz et al. 2011) and the black bear *Ursus americanus* Pallas, 1780 (Rodriguez-Martínez et al. 2008; Espinosa-Flores et al. 2012).

Articles published in conference proceedings have focused on carnivores and contain information about jaguars (Boyston and López-González 2005; Avila-Villegas and Lamberton-Moreno 2013), ocelots (Ávila-Villegas and Lamberton-Moreno 2013), black bears (Lara-Díaz et al. 2013) and pumas (González-Bernal et al. 2011). This type of work has also been done on the beaver *Castor canadensis* Kuhl, 1820 (Pelz-Serrano et al. 2005) and on the presence of some species of medium and large mammals (Bermudez-Enriquez et al. 2013). In general, publications that provide basic information about the presence and population trends for most species are lacking for northeastern Sonora. However the present information suggests that this is one of the regions with the highest species richness in Sonora (Caire 1978), and large-bodied mammals that have disappeared from other regions in Mexico still exist in the state (Morrison et al. 2007). Thus surveys are important here to assess current species richness and provide a basis for continued monitoring.

We have detected an information gap for virtually all registered families (i.e., Didelphidae, Sciuridae, Leporidae, Felidae, Canidae, Mustelidae, Mephitidae, Procyonidae and Tayassuidae). Many species identified in this study have uncertain conservation status, and it is likely that this situation is reflected at the regional level, particularly for those species classified in some risk category, both nationally (SEMARNAT 2010) and internationally (IUCN 2014). For example, the Arizona gray squirrel *Sciurus arizonensis* (Coues, 1867) and the American Badger *Taxidea taxus* are classified as threatened, but there are no studies in Mexico that allow a more precise evaluation of their conservation status.

In order to reach a consensus with experts about the identity of the recorded *Lepus*, two participants determined two different species in the series of photographic records that were sent to them (i.e., *Lepus alleni* Mearns, 1890 and *Lepus californicus* Gray, 1837),

whereas four experts identified only one species in the photos, *L. alleni*. We believe that the species recorded at the Ojos site corresponds neither of these two species, but to *Lepus callotis* Wagler, 1830 as there are over 500 records less than 20 km northeast of the sampling location (Bednarz and Cook 1984). Additionally, there are reasonable doubts concerning morphological characteristics to assign our records to either *L. californicus* or *L. alleni*. *L. callotis* can be distinguished from *L. alleni* by it is smaller size, shorter ears and whitish sides of the body rather than grayish sides (Best and Hill 1993a). From *L. californicus, L. callotis* can be distinguished by it is whitish rather than brownish-gray sides and white-tipped rather than black-tipped ears, the pelage of *L.callotis* is shorter and coarser than that of *L. calofornicus*. *L. callotis* also is more buff or fawn colored dorsally, the pale-gray rump patch blends into white sides, and the upper surface of the tail is black (Best and Hill 1993b). The presence of *Lepus callotis* would add a threatened species, according to Mexican Red List (SEMARNAT 2010) and the IUCN Red List (IUCN 2014). Thus, it is necessary to extend the monitoring to other vegetation types, as well as to capture a member of this group to validate the presence of one or more species.

The jaguar and ocelot are endangered in Mexico (SEMARNAT 2010) and internationally (IUCN 2014), and there are sparse records of these species in the borderlands region. The current monitoring sites correspond to marginal habitat where no breeding populations have been reported (Brown and López-González 2001) and records from these locations may be individuals in the process of dispersal, particularly in the case of jaguars. Jaguar and ocelot records that we obtained for this region indicate connectivity still exists towards the north end of the state, which is important in order to be able to establish populations.

Black bears present a special case in Mexico, where only populations distributed in the Sierra Madre Oriental are within a national risk category (SEMARNAT 2010), not considering the populations which still remain in the Sierra Madre Occidental and which we detected in this study. Our data suggests these other black bear populations may be in need of protection; we obtained few photographic records of females with cubs in only a few localities and records of solitary individuals, but we do not know if these were dispersing individuals or part of the local population. Further black bears have been reported in two other mountain ranges (Sierra Los Ajos and Sierra San Luis) at lower densities than in the Sierra Madre Oriental and United States (Espinosa-Flores et al. 2012); we can thus assume that there are still breeding populations in other mountain ranges, but it is likely that in some Sky Islands these are small and isolated. Likewise, the black bear is a species commonly hunted in the region, as it is thought to cause occasional damage to livestock, particularly during periods of prolonged drought. Some livestock producers in the region pay between 130–200 United States dollars (USD) per male bear and 340 for females (pers. obs.). We therefore have recommended that black bears be listed under some threat category at the Mexican Red List of threatened species (Lara-Díaz et al. 2014) and that information on their population density should be generated for other mountainous areas (e.g., Sierra La Madera, Sierra El Tigre).

Populations of game species such as white-tailed deer *Odocoileus virginianus* and mule deer *Odocoileus hemionus* (Rafinesque, 1817) are maintained by regional land owners because of the potential economic benefit they represent, in contrast to other species (e.g., large carnivores). We obtained a large number of photographic records of white-tailed deer during monitoring, which suggests that the conservation status of the species may be relatively good in the region. In the case of mule deer, few records were obtained, probably because monitoring sites were in marginal habitat for this species, which mainly occupies open areas (e.g., grasslands; Mackie et al. 2003), in contrast to the white-tailed deer. Differential habitat use by deer in the region, as well as their abundance must be considered in future studies, in order to establish adequate hunting management of both species.

Most species detected were widely distributed habitat generalists (e.g., *Canis latrans, Mephitis macroura*) and are not included in any official threatened species list (Caire 1978; Hall 1981; SEMARNAT 2010; IUCN 2014). However the status of the populations of these mammals, but more studies of these species could help inform conservation efforts for other species because of community effects. For example, it has been observed that the absence of large carnivores causes cascade effects, modifying the abundance of mesocarnivores, prey and plant communities, and it is possible that some more sensitive species may eventually disappear locally (Prugh 2009; Ripple et al. 2014).

Through this sampling effort, we recorded 25 species of wild terrestrial mammals, a richness that does not include seven species reported by Caire (1978) and Hall (1981). The absence of these may be due to the following factors: a) the studied habitat covered only marginally the habitat type preferred by these species b) the quality and actual amount of habitat are not adequate for them to be present, c) some species may have been extirpated locally, and d) some species have been extinct nationwide. However, this study alone was not sufficient to determine the reason that we did not detect these seven species.

One undetected species was the North American porcupine *Erethizon dorsatum* (Linnaeus, 1758), which is found in riparian vegetation habitats (Woods 1973). In

Mexico, it has been documented in temperate forests, thickets of mesquite, and thorn scrub (List et al. 1999). There is a resident population in the Janos-Nuevo Casas Grandes region in the state of Chihuahua (43 km southeast of monitoring sites, List et al. 1999). Because they exist close to the study area, we do not rule out their presence at the monitored sites. Despite this, we predict a probable decline in the quality and quantity of suitable habitat for porcupines in the region, which in combination with anthropogenic activities (Woods 1973) such as hunting (List et al. 1999) may be contributing to its local extirpation (at least at the study sites), thereby reducing the probability of detecting it. Lack of information and shortage of records for porcupines at the monitored sites makes it difficult to properly determine their conservation status in northeastern Sonora. Possibly monitoring with camera traps may not be the most appropriate method for detecting the species, and alternative sampling methods are necessary to detect and monitor the species (Griesemer et al. 1998).

The beaver *Castor canadensis* was considered to have been extirpated locally, but we expected to record this species in the Sierra San Luis, specifically at the Ojos site on the river Cajon Bonito, because their presence has been documented there (Pelz-Serrano et al. 2005). These authors estimated the presence of five beaver colonies in a river stretch of 18.5 km, based on following trails (tracks, droppings, and food caches). However, during eight years of field exploration (2005-2013) at the study site, we failed to detect either direct or indirect evidence. Because beaver habitat is associated with the presence of water bodies and riparian vegetation (Jenkins and Busher 1979), the habitat may have been degraded at different monitoring sites, but habitat availability and quality require evaluation. At the Ojos site, habitat appears adequate for beavers. In the study region, local people consider beavers a plague, because of damage caused to the trees that make up the riparian vegetation (Mario Cirett, pers. comm.), so extermination by residents coupled with a lack of perennial rivers, may have contributed to beaver extirpation at various localities.

Another species that we did not detect and for which we believe available habitat is limited is the bighorn sheep *Ovis canadensis* Shaw, 1804. There is a record of a 6–8 years old individual in the Ojos locality (Pelz-Serrano et al. 2006); this sighting was probably an individual who strayed from the population in the Peloncillo Mountains (McKinney et al. 2003). It is noteworthy that during eight years of field surveys at the observed site, a second record was not made and species monitoring at the Sky Island sites has not provided additional reports of the bighorn sheep. If populations did once exist in the area, we consider them to have been locally extirpated.

Finally, the Mexican wolf, *Canis lupus baileyi* Nelson and Goldman, 1929, and Mexican grizzly bear are extinct in the country since the mid-1970s, due to the predator extermination campaigns initiated in the United States and replicated in Mexico (Brown 1983; Brown 1996).

In Mexico, federal authorities (i.e. Federal Commission of Natural Protected Areas) have committed resources to determine the conservation status of species at risk, however, participation of state and local authorities participate in monitoring and species protection is important for successful conservation. The reintroduction of the Mexican gray wolf provides an example of the need for coordinated protection efforts: among a family group of five gray wolves released in October 2011 and another in March 2012, four were poisoned a couple of months after release, one was poached, and another was declared missing (Lara-Díaz et al. 2015).

The Sky Islands are located in a region of great mammal diversity (Caire 1997; Marshall et al. 2004; Morrison et al. 2007). We recommend that continuous wildlife monitoring, assessment of current distributions and population density studies are conducted, in order to determine the quantity and quality of available habitat. We also suggest the need to assess and identify the conservation status of each species, especially for those with no available information in Mexico, but which have some risk status (e.g., *Sciurus arizonensis*, *Taxidea taxus*). Likewise, monitoring needs to be expanded in the Sky Islands using alternative detection methods, such as box trapping or use of guns to collect specimens (Jones et al. 1996), in order to determine the presence of species that camera traps may miss. Ideally, inventories should include methods to detect species with small, medium and large body size, even if the species are not at risk of extinction or of hunting interest.

The species list that we present provides a temporal starting point towards a proposal for comprehensive management and conservation, but extending survey efforts to include monitoring medium and large mammals in other types of habitat such as scrub and grassland vegetation could help identify more species within the region and their conservation needs.

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APPENDIX

Photographic records for the 25 species of wild terrestrial mammals detected in four Sky Islands in northeast Sonora, Mexico.

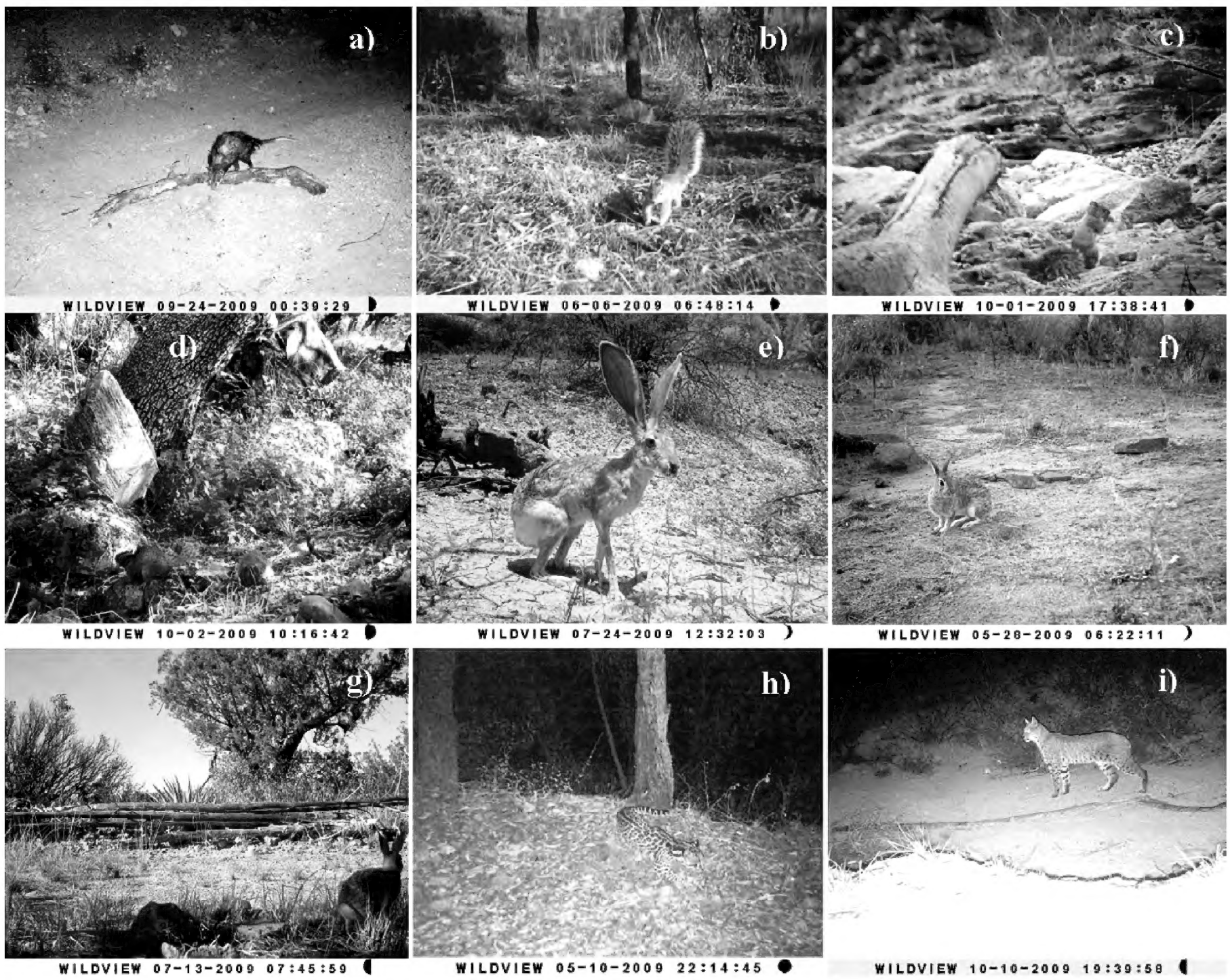

Figure A1. a) *Didelphis virginiana*; b) *Sciurus arizonensis*; c) *Sciurus nayaritensis*; d) *Otospermophilus variegatus*; e) *Lepus alleni*; f) *Sylvilagus audubonii*; g) *Sylvilagus floridanus*; h) *Leopardus pardalis*; i) *Lynx rufus* (*continued next page*).

Figure A1 (*continued***).** j) *Puma concolor*; k) *Panthera onca*; l) *Canis latrans*; m) *Urocyon cinereoargenteus*; n) *Ursus americanus*; o) *Taxidea taxus*; p) *Conepatus leuconotus*; q) *Mephitis macroura*; r) *Mephitis mephitis*; s) *Spilogale gracilis*; t) *Bassariscus astutus*; u) *Nasua narica*; v) *Procyon lotor*; w) *Pecari tajacu*; x) *Odocoileus hemionus*; y) *Odocoileus virginianus*.